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BLOOD-PRESSURES

Their Relation to Each Other and to
Physical Efficiency

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BLOOD-PRESSURES

THEIR RELATION TO EACH OTHER AND TO PHYSICAL EFFICIENCY *

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In this communication we desire to record the blood-pressure findings in a total of 742 males with particular reference to the diastolic and pulse pressures; also the relations between blood-pressure and physical efficiency.

METHODS

In these blood-pressure readings we used a mercury manometer of the usual type with 12 cm. cuff, and we made our determinations by the auscultatory method.

The maximum pressure was determined in all cases at the first sound. The minimum pressure in Series A was read at the time of disappearance of all sounds (fifth phase); and in Series B, more accurately at the point of the last clear sound preceding the final dull tones. This is known as the fourth phase. Obviously, then, we get a reading somewhat higher when we make our readings at the final sharp tone than if we wait for the disappearance of all sounds. The difference may be as much as 10 mm. and usually in the neighborhood of 5 mm. This difference, while noteworthy, is not sufficiently great to detract from the actual value of our figures for the minimum blood-pressure in Series A in the manner in which we use them.

The subjects in this study were students in their usual health, most of them between 15 and 25 years of age. While our records include the readings in both the erect and horizontal posture, the accompanying tables and figures refer only to the readings in the erect, the effect of change of posture on the arterial and venous pressures having been previously studied by us.¹

The method used in estimating the physical efficiency in this work is the one known as the "intercollegiate standard." It consists of adding the strength of back, plus strength of legs, plus strength of right and left forearms, plus lung capacity divided by twenty, plus body-weight divided

* From the Department of Student Health, Carnegie Institute of Technology.

1. Barach, J. H., and Marks, W. L.: Effect of Change of Posture without Active Muscular Exertion on the Arterial and Venous Pressures, *ARCHIVES INT. MED.*, 1913, xi, 485.

by ten. The last figure obtained is multiplied by the number of times the subject pulls up and dips his body by the strength of his arms and shoulder muscles. This gives us a very fair estimate of the individual's physical condition. For one to show a high total strength he must possess a good musculature, good coordination, an efficient circulatory and respiratory system, one which will respond properly and maintain itself during the effort required by the test.

MINIMUM PRESSURES

In the accompanying tables it will be noted that we do not give the average height of the blood-pressure readings of an entire series of cases, but rather do we give the actual number of cases which occurred at the various heights. We believe this to be more accurate and leading to truer conclusions.

TABLE 1.—AGE DISTRIBUTION IN A SERIES OF 552 CONSECUTIVE CASES

Age, Years	Cases
15 to 17.....	27
17 to 19.....	200
19 to 21.....	202
21 to 23.....	71
23 to 25.....	31
25 to 27.....	12
27 to 29.....	6
29 to 31.....	1
Over 31	2
Total	552

Maximum Pressure.—As heretofore stated, the maximum pressure was read at the first sound—by the auscultatory method. In 656 cases the distribution was as shown in Table 2.

TABLE 2.—DISTRIBUTION OF MAXIMUM PRESSURE IN 656 CASES

Mm. Hg.	Cases
90-100	7
100-110	23
110-120	112
120-130	204
130-140	153
140-150	95
150-160	45
160-170	14
170-180 }	3
180-190 }	
190-200 }	
Total	656

Out of these 656 cases, there are 594 under 150 mm. Hg.; these comprise 90 per cent. of the entire series. It has been our experience that just about 10 per cent. of the men come in presenting a blood-pressure considerably higher than normal at their first examination, but at a

subsequent examination it is found to be much nearer the normal level. This undoubtedly is due to the psychic effect of the examination.

Minimum Pressure, Series A.—Here the pressure was read by the auscultatory method at the disappearance of all sounds, with the results shown in Table 3.

TABLE 3.—MINIMUM PRESSURE READ BY THE AUSCULTATORY METHOD AT DISAPPEARANCE OF SOUNDS

Mm. Hg.	Cases	
30- 40	1	} 327 Cases = 96 %
40- 50	2	
50- 60	4	
60- 70	20	
70- 80	82	
80- 90	140	
90-100	78	}
100-110	9	
110-120	1	
120-130	1	
Total	338	

The majority of these, 96 per cent., had a minimum pressure under 100 mm. Hg.

Minimum Pressure, Series B.—In these cases the point of the minimum pressure was read at the last clear sound preceding the final dull tones (Table 4). It is now generally agreed that this is the exact point of the minimum pressure.

TABLE 4.—MINIMUM PRESSURE READ AT THE LAST CLEAR SOUND

Mm. Hg.	Cases	
40- 50	1	} 273 cases or 87 %
50- 60	4	
60- 70	12	
70- 80	41	
80- 90	94	
90-100	121	
100-110	27	}
110-120	9	
120-130	3	
Total	312	

In this series, in which the point of minimum pressure is read earlier than in Series A, we find that over 87 per cent. of the cases present a minimum pressure under 100 mm. Hg, and that 256 cases, or 82 per cent., occur between the points of 70 mm. and 100 mm. Hg.

We see, then, that when the minimum pressure is read at the fourth phase, 87 per cent. of the cases are found to be not over 100 mm. Hg, while at the end of the fifth phase 96 per cent. of the cases do not exceed 100 mm. Hg.

In Series B, in which the pressure was read at the fourth phase, the 13 per cent. which had a maximum pressure of over 100 mm. were reexam-

ined. We then found that the first was only a temporary response to the psychic effect of the examination and that in only two cases did the minimum blood-pressure exceed 100 mm., one showing a minimum blood-pressure of 105 and the other 102 mm. Hg.

Minimum Pressure in All Cases.—If we allow for clinical purposes that the difference between the end of the fourth and fifth phase in a large series of cases such as this one is a negligible factor, by combining Series A and Series B we get the results shown in Table 5.

TABLE 5.—MINIMUM PRESSURE IN ALL CASES		
Mm. Hg.	Cases	
30- 40	1	} 600 cases or 92 %. Not over 100 mm. Hg
40- 50	3	
50- 60	8	
60- 70	32	
70- 80	123	
80- 90	234	
90-100	199	
100-110	36	
110-120	10	
120-130	4	
130-140	..	
Total	650	

Pulse-Pressures.—In Series A and B we have pulse-pressure readings in 629 cases. The normal variation in the size of the pulse-pressure is seen to be quite marked.

TABLE 6.—PULSE-PRESSURES IN SERIES A. MINIMUM PRESSURE READ AT THE FIFTH PHASE

Mm. Hg.	Cases
10-20	9
20-30	30
30-40	68
40-50	76
50-60	62
60-70	43
70-80	17
80-90	7
Total	312

TABLE 7.—PULSE-PRESSURE IN SERIES B. MINIMUM PRESSURE READ AT THE FOURTH PHASE

Mm. Hg.	Cases
5- 10	1
10- 20	11
20- 30	45
30- 40	79
40- 50	79
50- 60	53
60- 70	25
70- 80	18
80- 90	5
90-100	1
Total	317

Tables 6, 7 and 8 show clearly that we may hold the usual pulse-pressure as ranging between 20 and 70 mm. Hg, in healthy persons of the ages here referred to.

TABLE 8.—PULSE-PRESSURE IN SERIES A AND B COMBINED

5- 10.....	1	
10- 20.....	20	
20- 30.....	75	} 560 cases or 88%. Between 20 and 70 mm. Hg.
30- 40.....	147	
40- 50.....	155	
50- 60.....	115	
60- 70.....	68	
70- 80.....	35	
80- 90.....	12	
90-100.....	1	
Total.....		629

RELATION BETWEEN THE PULSE-PRESSURE AND DIASTOLIC PRESSURE

Strassburger² attempted to find a blood-pressure quotient by dividing the pulse-pressure by the maximum pressure, but that has been shown to be erroneous. It has recently been stated by Stone³ that the pulse-pressure in the normal individual is equal to 50 per cent. of the diastolic pressure, and that for clinical purposes we may assume that, when the pulse-pressure is over 50 per cent. of the diastolic pressure, we are dealing with cardiac overload. If this theory could have been proved, it would have been an important advance in our clinical work.

We set forth here the findings in 742 cases. Series A has its slight error on account of the minimum pressure having been read at the fifth phase, while in Series B this element is eliminated. The figures represent the percentage relation of pulse-pressure to diastolic pressure. Our formula is D.P.:P.P.:100:×.

TABLE 9.—SERIES A. MINIMUM PRESSURE READ AT FIFTH PHASE

Per Cent.	Cases			
10- 20.....	10			
20- 30.....	24			
30- 40.....	48			
40- 50.....	49	} 108 cases, 30%	} 201 cases, 60%	} 264 cases, 70%
50- 60.....	59			
60- 70.....	45			
70- 80.....	39			
80- 90.....	23			
90-100.....	14			
100-110.....	16			
110-120.....	2			
120-130.....	1			
130-140.....	5			
Total.....		335		

2. Strassburger: Arch. f. klin. med., 1905, lxxxv.
3. Stone, Willard, J.: The Clinical Significance of High and Low Pulse-Pressures with Special Reference to Cardiac Load and Overload, Jour. Am. Med. Assn., Oct. 4, 1913, p. 1256.

TABLE 10.—SERIES B. MINIMUM PRESSURE READ AT THE FOURTH PHASE

Per Cent.	Cases			
5- 10.....	2			
10- 20.....	8			
20- 30.....	44			
30- 40.....	63			
40- 50.....	73	} 141 cases, 34%	} 260 cases, 63%	} 333 cases, 81%
50- 60.....	68			
60- 70.....	56			
70- 80.....	29			
80- 90.....	32			
90-100.....	11			
100-110.....	13			
110-120.....	1			
120-130.....	2			
130-170.....	5			
Total		407		

In Series B, in which the pulse-pressure is smaller than in Series A, we note that a greater number of cases occur in the lower percentages. In both A and B we may note that the greatest number of cases do occur near the 50 per cent. mark, and if we were to strike an average it would be close to 50 per cent.; yet this would be far from representing the actual truth. These tables show that there is a wide range both above and below the 50 per cent. mark in normal individuals. Our findings here would warrant only a statement that the pulse-pressure equals from 20 to 80 per cent. of the diastolic pressure in about 75 per cent. of the cases. One objection may be offered to our deductions, and that is the comparative youth of the subjects. Considering the age, the physical development, the height of the blood-pressures, and in the light of our previous observations on older subjects, we incline to believe this objection a negligible factor, and that our findings here are representative for normal persons up to middle life. Other observations on older individuals in health and in various disease conditions with which we expect to deal in another paper, will bear out this point.

RELATION OF TOTAL STRENGTH TO BLOOD-PRESSURES

We have pointed out previously⁴ that there is no constant relation between blood-pressures and total strength. In Table 11 we show that there is no definite relation between the pulse-pressure per centage of diastolic pressure and circulatory efficiency, such as is indicated by the general physical efficiency.

The upper 146 cases give a pulse-pressure equal to 56 per cent. diastolic pressure, while the lower 150 cases (excluding the last three) give

4. Barach, Joseph H.: Physiological and Pathological Effect of Severe Exertion (the Marathon Race) on the Circulatory and Renal System, THE ARCHIVES INT. MED., 1910, v, 382.

a pulse pressure equal to 61 per cent. of diastolic pressure, showing that there is no relation between the total strength and pulse-pressure per cent. of diastolic pressure.

It is particularly worthy of note that the man who showed the highest total strength (1724), had a pulse-pressure equal to 100 per cent. of the diastolic pressure. This man certainly had no evidence of cardiac overload. Also that one subject whose strength was only 651 (the fourth lowest of the 344 cases), showed a pulse-pressure equal to 80 per cent. of the diastolic pressure.

TABLE 11.—THE RELATION OF TOTAL STRENGTH TO BLOOD-PRESSURES

Total Strength	Cases	Av. Str.	Average Max. P.	Average Min. P.	Average P. P.	Average P. P. %
400- 500	1	477	117	75	42	56
400- 500	2	445	134	82	50	62
600- 700	1	651	126	70	56	80
600- 700	5	860	129	66	44	54
600- 700	3	647	121	80	41	54
700- 800	5	774	129	88	41	47
800- 900	5	860	129	66	44	54
800- 900	10	865	123	75	47	64
200- 900	35	871	126	84	41	51
900-1,000	3	927	130	83	46	59
900-1,000	19	950	126	81	42	53
1,000-1,100	28	1,045	121	78	42	51
1,000-1,100	4	1,093	117	83	33	45
1,000-1,100	25	1,048	138	67	51	66
1,100-1,200	14	1,161	123	84	39	48
1,100-1,200	34	1,152	130	84	45	54
1,100-1,200	27	1,148	124	75	46	66
1,200-1,300	4	1,243	136	86	49	57
1,200-1,300	22	1,250	135	83	50	66
1,200-1,300	28	1,242	127	80	45	58
1,300-1,400	5	1,331	120	79	40	52
1,300-1,400	9	1,331	135	86	47	55
1,300-1,400	13	1,347	121	76	44	63
1,400-1,500	5	1,456	133	89	44	50
1,400-1,500	12	1,437	137	85	50	60
1,400-1,500	8	1,465	128	76	50	66
1,500-1,600	2	1,566	121	85	36	42
1,500-1,600	8	1,542	133	80	58	73
1,500-1,600	4	1,537	129	84	45	54
1,600-1,700	1	1,633	132	70	62	88
1,600-1,700	1	1,658	115	68	47	69
1,700-1,800	1	1,724	140	70	70	100

Total..... 344

Comparing the weak and strong halves of the series, which is representative of the subjects who are more likely and those who are least likely to have circulatory inefficiency and cardiac overload, we see that the pulse-pressure percentage of diastolic pressure can offer us no reliable index.

In a former work⁴ it was shown that the size of the pulse-pressure is influenced by the systolic pressure, and that the systolic pressure is much more responsive, even to slight influences, than is the diastolic

pressure. We must also take into this consideration the fact that the unit of diastolic pressure has a greater value than the unit in systolic pressure.

As time goes on and our observations accumulate and are being interpreted, we believe that more and more importance will be attached to the height of the minimum pressure, and that the height of the maximum pressure will be considered of lesser clinical import than heretofore. Certainly the maximum pressure alone is of no value excepting as a starting-point for a guess as to the activity of the circulatory system.

SUMMARY

1. In 90 per cent. of a series of 656 healthy young men the maximum blood-pressure was under 150 mm. Hg. It would be still lower if we could eliminate psychic effect.

2. In 96 per cent. of a series of 338 cases the minimum pressure when read at the fifth phase did not exceed 100 mm. Hg.

3. In 87 per cent. of a series of 312 cases the minimum pressure, when read at the fourth phase, did not exceed 100 mm. Hg.

4. On reexamination of the 13 per cent. in the series of 312 cases, we found that 99.4 per cent. had a minimum blood-pressure not over 100 mm. Hg.

5. In 92 per cent. of the total 650 cases the minimum pressure did not exceed 100 mm. Hg at the time of the first examination.

6. In 88 per cent. of a series of 629 cases the pulse-pressure ranged between 20 and 70 mm. Hg.

7. There is no constant relation between the pulse-pressure and the diastolic pressure. In 75 per cent. of a series of 742 cases the pulse-pressure comprises anywhere from 20 to 80 per cent. of the diastolic pressure.

8. There is no relation between physical efficiency, which also means circulatory efficiency, and pulse-pressure percentage of diastolic pressure. In a series of 344 cases, the poorer half gave practically the same pulse-pressure to diastolic pressure percentage as the stronger half, with their better circulatory system.

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